Natural gas
The construction of a new civilization

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Foreword

Natural gas (NG) is a mix of light hydrocarbons which, in room temperature and standard pressure, remains as a gas. In nature, it is originally found in accumulations of porous rocks in the subsoil (whether terrestrial or marine). It is often associated to petroleum.

To all intents and purposes, the mixes of gas hydrocarbons in which molecules of methane (CH_4) prevail are called natural gas. In practice, gas is also made up of heavier molecules such as ethane, butane, propane and others. All the gas hydrocarbons can also be extracted from crude oil through the refining processes or from coal, through its gaseification in processes called Coal-to-Gas (CTG). Especially butane and propane, extracted in the refinery, in the coal gaseificators or in the natural gas processing units, make up the so-called liquefied petroleum gas (LPG).

Chemically speaking, LPG is as natural as methane. However, in terms of the organization of the supply chain, the methane industry constitutes the so-called natural gas industry, which is often distinct from the LPG industry. NG and LPG have their own characteristics that direct them mainly towards specific uses. There is a certain degree of competition and substitution between them, but they can also be considered as complementary. The gases produced from coal are called synthetic or manufactured. Those gases prevailed and constituted the birth of the gas industry in many parts of the world, including Brazil, between 1700 and 1800. On a global scale, NG overcame them during the 20th Century and in the beginning of the 2000's.

The focus of this essay will be on natural gas, even though many of the topics dealt with here apply to the greater set of the fuel gases. Specifically, the gas civilization concept proposed here, although developed mainly according to the perspectives announced for the NG industry, necessarily includes larger space that must be occupied by all forms of fuel gases, including both LPG and CTG.

The strategic role of natural gas has increased as an energy source to the world, mainly due to its lower environmental impact compared to the other fossil energy sources. For example, the use of natural gas in adequate equipment tends to be less pollutant than the burning of diesel oil. The burning of fuel gases adequately processed and in correct equipment is almost exempt of pollutants such as sulfur oxides, solid particles and other toxic products, thus allowing the consumer to use gas directly.

The burning of natural gas also has other advantages. For example, gas enables combustion with a high thermal yield, as well as simple control and regulation of the flame. Therefore, it is possible to reduce the intensity of energy consumption in the industry, in businesses or in households. Besides, since it permits the flame and/or the combustion gases to be in direct contact with the products, the use of gas in several industries contributes for the increase of these products' quality and competitiveness.

Gas can still present both savings and environmental advantages when it is used in the transportation sector, substituting gasoline or diesel oil. In Brazil, mainly due to a price policy and to tributary differences among the fuels, natural gas had a great consumption increase for automotive purposes, mainly among cab fleets, substituting gasoline. Between January 2001 and November 2006, the vehicle natural gas (VNG) consumption increased from 1.35 to 6.71 million cubic meters per day (MMm^3/d), which represented an annual average growth of approximately 38% (*Revista Brasil Energia*, 2006).[1]

The versatility of use is one of the great advantages of natural gas. In Moutinho dos Santos et al. (2002) there are detailed descriptions of the best uses and the main advantages of using natural gas in several segments of the economic activity, including the industry, businesses, the residential sector and transportation, as well as in the energy sector itself, which can use gas as a primary fuel for its transformation processes. Besides, natural gas can be used as raw material of the chemical industry. It is used to make products with much higher value-added, such as plastics and lubricants. Even if that relation between energetic and non-energetic uses of the gases can't be dealt with in this article, it is clear that the gas civilization concept necessarily includes both uses.

A brief outlook of the international energetic reality

Talking about long-term energetic perspectives is an unpleasant task. Those kinds of predictions are almost impossible, since nobody can know what will happen in a distant future. The technologies, which are men's greatest concerns, the social behaviors and the policies, as well as the economic agents involved and both the capital and the natural resource stocks undergo drastic changes as time goes by. That occasionally makes the current realities and trends obsolete or scarcely representative in the definition process of the future opportunities.

Even acknowledging such limitation, this brief outlook of the international energetic reality is devoted to the simple exercise of summarizing some energetic scenarios presented by competent institutions. This is not about trying to search for any indication of truth about an unknown future. By the way, as will be discussed throughout the text, one can criticize the long-term view of those institutions, which don't seem to capture the most complex dimensions and the most profound impacts of important technological advances, which can turn their exercises scarcely relevant.

All the scenarios described acknowledge that the world is undergoing a period of great transformations, many of which are spurred by uncertainties regarding key problems that can affect the planet as a whole. Not much is known about how those problems might evolve and what impacts they might have on humanity. Besides, it is impossible to predict what political attitudes and technologies men will adopt to solve them. Only when we get to know these solutions we will be able to start imagining which will be the necessary energetic base to feed the future of the planet.

The perception that society develops about the future is as important as reality itself, since the perceptions cause immediate changes in behavior, which in turn alter the relative prices of goods and services. The uncertainties about the future create a current demand for precaution solutions. The economic signs tend to modify themselves to make those solutions viable, transforming the strategies of the economic, political and social agents. But which will be the new victorious and later generalized strategies? That is still a great unknown that this text can't solve.

Much will depend on how fast the behaviors will change, the perceptions of the future will materialize and the technologies will develop. Those are complex themes, the solutions of which will never be trivial and short-term. Among others, two major problems may stand out, which sooner or later human beings will have to tackle, namely: (i) the problem of the greenhouse gases emissions and the global warming of the planet; and (ii) the end of the world's oil reserves, besides increasingly serious geopolitical problems since the world will increasingly depend on oil reserves located in delicate areas of the planet.

The following scenarios only start to contemplate the uncertainties about those themes, but they still seem to minimize the changes that such uncertainties might cause in the relationships between man and energy. The energy consumption predictions for the future are based on positive extrapolations of the current consumption models. However, as will be discussed with more details throughout the text, the technological possibilities and the energy needs of men might change radically, making all the scenarios obsolete.

Any way, a comparative reading of distinct views of the future, even if we do acknowledge its low probability of success as a prediction instrument, helps to identify some solid trends that might have a greater capacity to influence that future. Its reach will depend on its capacity to mobilize the social forces, to amalgamate financial, technological and human resources. Besides, it will also depend on the existence of a viable natural resources base which is sustainable. In other words, one that contemplates an acceptable distribution between the current needs and those that might be expected for tomorrow.[2]

In its study called *World Energy Outlook 2006* (IEA, 2006a), the International Energy Agency (IEA) establishes both an "alternative and a reference scenario to 2030". Table 1 describes the IEA prediction regarding the evolution of the global energy matrix and its distribution by primary energy source. In the reference scenario, global primary energy consumption is expected to grow approximately 1.6% per year between 2004 and 2030, reaching a total consumption of 17.1 billion tons of oil equivalent (toe). The annual consumption expansion predicted for the period between 2004 and 2030 is of approximately 6 billion toe. Therefore, in 2030, the world will consume approximately 53% more than the current energy demand. For the same period, a reduction of the annual average growth rate of energy consumption is predicted.

The International Energy Agency predicts that in the reference scenario fossil fuels will remain as the prevailing primary energy sources. Between 2004 and 2030, energy consumption from fossil sources is expected to grow faster than the collective demand for both renewable and nuclear sources. During the entire period, fossil fuels will always represent more than 80% of the global demand for energy. Among those, natural gas will present the highest annual growth rate, 2.0%. Therefore, it will continue its path of growing shares in the global energy matrix: in 1980, it represented 17% of the global energy consumption and its share is expected to reach 22.6% in 2030. In turn, the renewable energy sources will have a solid growth during the period, though its relative share as a whole, including nuclear energy, will decrease from 19.6% in 2004 to 18.8% in 2030.

According to IEA, the reference scenario is a trustful indication of how the energetic future of the planet might be characterized if the current development patterns are maintained. The Agency acknowledges that this scenario is unsustainable. The energy provision conditions to meet the needs of the world economy in the next 25 years would be very vulnerable, requiring investment sums that are hard to obtain, and that are not currently in circulation. Besides, an environmental catastrophe can be expected as well as serious compromising of the nations' energetic security, with sudden, frequent and profound interruptions of the energy supply.

Table 1
Alternative and Reference Scenarios
Evolution of the world's energy matrix for primary energy

	2004		Reference scenario			Alternative scenario			Differences between both scenarios in 2030	
			2030		2004-2030	2030		2004-2030		
		%[2]	(MMtoe)[1]	%[2]	% [3]	(MMtoe)[1]	%[2]	% [3]	(MMtoe)[1]	%[4]
Coal	2, 773	24.8	4, 441	26.0	1.8	3, 512	22.8	0.9	-929	-20.9
Oil	3, 940	35.2	5, 575	32.6	1.3	4, 955	32.2	0.9	-620	-11.1
NG	2, 302	20.5	3, 869	22.6	2.0	3, 370	21.9	1.5	-499	-12.9
Nuclear	714	6.4	861	5.0	0.7	1, 070	6.9	1.6	209	24.3
Hydraulic	242	2.2	408	2.4	2.0	422	2.7	2.2	14	3.4
Biomass and waste	1, 176	10.5	1, 645	9.6	1.3	1, 703	11.1	1.4	58	3.5
Other renewable	57	0.5	296	1.7	6.6	373	2.4	7.5	77	26.0
Total fóssil	9, 015	80.5	13, 885	81.2	1.7	11, 837	76.8	1.1	-2, 048	-14.7
NG / Total fossil [5]		25.5		27.9			28.5			
Nuclear + renewable	2, 189	19.5	3, 210	18.8	1.5	3, 568	23.2	1.9	358	11.2
Total	**11, 204**	**100**	**17, 095**	**100**	**1.6**	**15, 405**	**100**	**1.2**	**-1, 690**	**-9.9**

Where:

1 – In million of tons of oil equivalent.
2 – Share % of the source in the annual energy matrix.
3 – Average annual growth % of the source between 2004 and 2030.
4 – Increase or decrease % of the source in 2030 between the reference and the alternative scenarios.
5 – Share % of the consumption of natural gas in total fossil energy consumption in the year.
Source: International Energy Agency.

To make the global energy system more sustainable, IEA proposes an alternative scenario (see Table 1 again), the materialization of which involves great challenges. According to the Agency, to move towards that scenario instead of the reference one, it is necessary courage to act, even before political difficulties and great controversies regarding the great themes.

This is a future option considered as plausible, reachable through measures the costs of which may be considered as acceptable and that don't exceed the amount of the benefits expected. Everyone will be able to use those benefits, both energy suppliers and consumers, and both from more advanced nations and from economically and socially developing countries. It is important to point out that the latter are often vulnerable and subject to an unsustainable and inefficient energy matrix. Scenarios that require unrealistic efforts from them, given the lack of available resources, are barely believable.

The alternative scenario that the IEA considers as plausible includes efforts to improve the efficiency both of energy production and consumption, as well as initiatives to reduce the dependence on the global energy matrix of the fossil fuels. The prediction is that the policies that would sustain that scenario could provide significant savings in energy consumption compared to the reference scenario. Therefore, in 2030, the total primary energy consumption could be approximately 10% (or 1.7 billion toe) lower. The CO2 emissions related to the energy could be cut by 16% in 2030, compared to the framework set by the reference scenario. Therefore, this not about any more radical view of the future, in which the relationship between man and energy would undergo a profound transformation.

In IEA's alternative scenario, between 2004 and 2030, the annual average growth rate of the consumption of fossil energy sources will be 1.1%, which is less than that of total energy consumption, 1.2%. That will require a much higher growth, 1.9%, for the set of renewable and nuclear energy sources. Specifically, when both proposed scenarios are compared to 2030, IEA suggests that a reduction of fossil energy sources consumption of approximately 15% would be mainly compensated through a 24.3% increase of nuclear energy and of a 26% increase of other renewable energy sources, such as wind and solar power. It should be noted that this a scarcely alternative world compared to a current energy matrix that seeks to favor the production and the use of electricity as the main final energy source. There is little challenge to that role played by electricity, which will be discussed later on.

Nevertheless, in 2030, the world would still have an almost 77% dependence on fossil energy sources. When both scenarios are compared, the consumption of the set of fossil energy sources decreases. However, between 2004 and 2030, natural gas will be the only fossil energy source that will present an annual average expansion greater than total energy consumption in both scenarios. Considering the consumption of the set of fossil energy sources, the share of natural gas will grow from 25.5% in 2004 (it had been 20.2% in 1980) to 27.9% in 2030 (in the reference scenario) and 28.5% (in the alternative scenario).

Another institution that produces scenarios acknowledged in the whole world is the Anglo-Dutch company Shell. Its study called Exploring the Futures: Energy Needs, Choices and Possibilities, (Shell, 2001), establishes scenarios to 2025 and 2050. Table 2 presents a summary of its figures. There are two possible evolutions called Business-as-usual dynamics and Spirit of Coming Age. In the former, it is presupposed that total primary energy consumption's growth rates will decrease from the year 2000 on, growing at an average of 1.8% per year (between 2000 and 2025) and of 1.2% per year (between 2025 and 2050).

The Spirit of Coming Age scenario predicts a much more aggressive process for the economic and social development of the less favored nations, which will benefit from the processes of globalization and economic expansion of the richest nations. Pressures on the world energy system will be much greater.

At first, the measures for the growth of energetic efficiency and for the diversification of the energy sources will be insufficient to detain the increasing demands of the emerging countries that are experiencing rapid economic growth. Therefore, the average annual rate of the global primary energy consumption expansion will be 2.5% between 2000 and 2025, that is, substantially greater than the 1.8% rate of the previous period between 1975 and 2000. Between 2025 and 2050, the average growth rate will decrease to 1.6% per year. That still represents an important new demand that must be met each year.

In both scenarios from Shell, solid increases are expected on the consumption of energy from renewable sources, and, according to the Spirit of Coming Age, the demands for theses alternative energy sources will be very robust between 2000 and 2050. Besides, in this scenario, unlike the proposal for the Business-as-usual dynamics, the share of nuclear energy will be always growing. Between 2025 and 2050, the introduction of new generation technologies from nuclear source will spur a new nuclear boom, surpassing the average growth expected for total energy consumption.

Despite the advancement of the renewable and nuclear energy sources, the world will still depend heavily on fossil energy. By 2025, fossil energy sources will represent almost 80% of the global energy matrix, and its demand will be greater in the case of the Spirit of Coming Age. Between 2000 and 2025, a solid growth in the global energy consumption can't be obtained without the growing use of oil and coal. After that, the fossil energy sources will start to lose their relative share, representing just over 60% of the energy matrix in 2050. In the Spirit of Coming Age the role of both oil and coal can be reduced in a faster pace.

Among the fossil energy sources, natural gas will gradually take the leading role. For both scenarios by Shell, between 2000 and 2025, the average annual growth of the natural gas consumption will be greater than total energy consumption. Between 2025 and 2050, natural gas will lose dynamism, but that loss will be partially compensated by the advance of new technologies such as Coal-to-Gas, that is, the production of methane or of hydrogen from coal, thus using the same transportation, distribution and final energy use infrastructure built for natural gas in the previous period.

In the Business-as-usual dynamics scenario, natural gas is expected to represent 26% of the world's energy matrix by 2025, later reducing its share to 21% by 2050. Considering NG and CTG, such shares will be approximately 27% by 2025 and 23% by 2050. In the Spirit of Coming Age scenario, natural

gas will become even more relevant. It will represent 29% of the world's energy matrix by 2025 (or 30% for NG and CTG), and 27% by 2050 (or more than 35% for NG and CTG). In that scenario, the greatest restrictions to the use of oil and coal, as well as the rapid growth of the global energy consumption can only be compensated through a relevant increase of the natural gas consumption.

Table 2 – Energy scenarios by Shell to 2025 and 2050

	Annual energy consumption (in exajoules [1])				**Average annual growth rate %**		
Business-as-usual dynamics	**1975**	**2000**	**2025**	**2050**	**1975-2000**	**2000-2025**	**2025-2050**
Total primary energy	256	407	640	852	1.9%	1.8%	1.2%
Oil	117	159	210	229	1.2%	1.1%	0.3%
Coal	70	93	128	118	1.1%	1.3%	-0.3%
CTG – Coal to Gas (methane and hydrogen produced from coal)	0	0	4	16	-	-	5.8%
Natural gas	47	93	167	177	2.7%	2.4%	0.2%
Nuclear	4	29	35	32	8.1%	0.8%	-0.4%
Hydraulic	17	30	41	39	2.4%	1.3%	-0.3%
Biofuels	0	0	5	52	-	10.2%	10.1%
Other renewable	0	4	50	191	8.7%	11.2%	5.5%
Spirit of coming age	**1975**	**2000**	**2025**	**2050**	**1975-2000**	**2000-2025**	**2025-2050**
Total primary energy	256	407	750	1, 121	1.9%	2.5%	1.6%
Oil	117	159	233	185	1.2%	1.6%	-0.9%
Coal	70	93	150	119	1.1%	1.9%	-0.9%
CTG – Coal to Gas (methane and hydrogen produced from coal)	0	0	6	97	-	-	11.6%
Natural gas	47	93	220	300	2.7%	3.5%	1.3%
Nuclear	4	29	46	84	8.1%	1.9%	2.4%
Hydraulic	17	30	49	64	2.4%	2.0%	1.1%
Biofuels	0	0	7	108	-	11.8%	11.8%
Other renewable	0	4	38	164	8.7%	9.9%	6.0%

Business-as-usual dynamics	1975	2000	2025	2050
Share % of fossil energy in total primary energy	91.4%	84.8%	79.5%	63.4%
Share % of NG in total primary energy	18.4%	22.9%	26.1%	20.8%
Share % of NG and CTG in total primary energy	18.4%	22.9%	26.7%	22.7%
Share % of NG in total fossil energy	20.1%	27.0%	32.8%	32.8%
Share % of NG and CTG in total fossil energy	20.1%	27.0%	33.6%	35.7%

"Spirit of Coming Age"	1975	2000	2025	2050
Share % of fossil energy in total primary energy	91.4%	84.8%	81.2%	62.5%
Share % of NG in total primary energy	18.4%	22.9%	29.3%	26.8%
Share % of NG and CTG in total primary energy	18.4%	22.9%	30.1%	35.4%
Share % of NG in total fossil energy	20.1%	27.0%	36.1%	42.8%
Share % of NG and CTG in total fossil energy	20.1%	27.0%	37.1%	56.6%

(1) 1 exajoule = 1 billion GJ; 1 ton of oil equivalent = 42.7 GJ
Source: Shell.

In the Spirit of Coming Age scenario, natural gas will represent more than 35% (by 2025) and 43% (by 2050 – and more than 55% considering NG and CTG) in the total of fossil energy sources. By 2050, natural gas alone will be the world's main energy source (and its consumption will be equivalent to that of oil and coal combined). In the Business-as-usual dynamics, natural gas will maintain its position as the world's third most important energy source, in front of coal, but surpassed by other renewable energy sources (including solar and wind).

In the same way as in the case of IEA, even without making it explicit, Shell also suggests scenarios in which the growing role of electricity as the final energy to be consumed is unquestionable. The focus of both institutions is to map a future of new technologies, the main goal of which is to convert different primary energy sources into electricity.

The construction of a gas civilization

It is always worth restating that none of the scenarios studied above represents an attempt to predict the future. It can be observed that the great figures and the main directions expected for the global energetic system converge. Based on a comparative view, several "solid trends" stand out. The most important one is the growing role that natural gas is expected to occupy in the world's energy matrix in the next fifty years. In all future perspectives, it

will present a consumption growth much greater than that of oil, of coal and of the total primary energy consumption.

According to those studies, natural gas is expected to be the great transition energy source between an energetic world dominated by coal and oil, and another one with more diversified energy sources and increasingly dominated by renewable energy sources. However, it can also be said that the world is moving towards a greater energetic diversification, but with an increasingly leading role by the fuel gases, be them natural or produced from other energy sources such as coal or oil itself. Therefore, one can speak of the birth of a gas civilization, which will characterize the world's energy matrix throughout this 21st century.

The range of applications makes natural gas a potential competitor to almost all the other energy sources, including electricity. Gas competes with coal or with nuclear energy for electricity generation, but it can also substitute electricity with great advantages in most processes in which the latter is used for thermal purposes (production of heat or cold). For example, there should be a preference for gas in relation to electricity not only for water heating in the households, but also in centralized refrigeration systems. Thus, the fuel gases have a scarcely explored potential in the scenarios presented, namely to reformulate the relationship of men with the final energy that they really need.

Nowadays almost all the useful energy extracted from the primary sources has thermal energy as a goal or as an inevitable intermediate process. The only exceptions are the hydraulic and wind primary energy sources for lighting and to the electromotion power. The different forms of final energy that men really need are produced from thermal energy. Therefore, there are at least two big transformation processes to be followed and involving its respective energy losses, between the primary energy and the final energy consumed.

In the scenarios presented above, it is stated implicitly that gas will become the most used fossil fuel, because its consumption for electricity production is expected become very important, with very vigorous annual growth rates. In all scenarios, it is always admitted that there will be an explosive growth of electricity consumption. Therefore, this represents a growing pressure on the matrix of primary energy sources. In the current information Era, the planet is becoming increasingly voracious in terms of electricity consumption.

All the scenarios presented above take that hypothesis for granted without much questioning and are directed towards the issue of finding strategies that permit its sustainability in the long term. Therefore, it becomes urgent to modify the growing demand curve for fossil energies, increasing the energetic supply security of the countries, through the greater diversification of the energy sources and reducing the impacts of the fossil fuels on the environment.

In fact, that stance reflects a view to always face the energetic problem from the supply side. According to that system, the strategies and policies of the countries aim at defending the model of their energy matrix without rethinking substantially the strategies for the final use of the energy. The presupposition is that the demand for energy will continue to increase and the possibilities of efficiency increase and energy saving in the final uses are not considered.

To do that, it is necessary to reduce the influence of the fossil fuels (and specifically of oil, since there are increasing perceptions that oil is becoming ever rarer and that it is the great villain of global warming). Growing uses of gas are being promoted (and, as a contradiction, occasional returns to coal) to continue to produce ever more electricity. Besides, an increase of the use of nuclear energy and the development of new renewable energy sources for electricity generation are encouraged.

This is already a world that, according to what has been described in the scenarios presented above, takes natural gas to an eminent position and even one of leadership in the global energy matrix. However, the concept of a gas civilization is even more comprehensive.

The technological advances in the different economic sectors require the availability of thermal energy with high quality, versatility and supply security. Such characteristics that the consumers require favor the use of natural gas instead of other energy sources. Even for the digital man and that from the information Era, the share of electricity in its total energy consumption should not be greater than 20% to 25%. The overcoming of those figures indicates that the electricity required must be in use for thermal purposes. Therefore, electricity, which needed several transformation steps to be obtained, may be substituting, for example, natural gas as a source of thermal energy. An example of that can be seen in the results of a survey about electricity uses in households in Brazil (Procel/PUC, 2005). It shows that almost 80% of the electricity consumed in the households go to the generation of heat or cold (45% for refrigerator and freezer, 17% for electric shower and 16% for air-conditioner). Those are uses in which the substitution of electricity for gas would be technically possible.

Those issues don't show up in the scenarios above. They only show an unrestrained search for growing electricity supplies based on an exaggerated electrification process, which leads to questionable electricity uses, substituting other energy sources that could produce the heat (or cold) directly or the motion power.

In the world, the ever growing use of electricity, produced from fossil energy sources, without a profound questioning about the rationality of that same electricity being used as final energy, makes the useful energy that humanity actually consumes be less than 25% of the required primary energy.

Therefore, always growing and unnecessary pressures were imposed on the primary energy source matrix to be explored.

It is possible to maintain such a situation because the economic value of the energy has decreased quickly in relation to the wealth produced by the society (Moutinho dos Santos, 2006). Therefore, humanity, especially the most developed and powerful nations, have a great capacity to sustain energetic losses, since the share of the energy cost in the total wealth that it is able to generate is low and always decreasing. However, until now, that same humanity has always been freed from greater guilt of the environmental and social impacts generated from its energetic consumption. Only now does its commitment to the global environmental problems is starting to take shape.

The scenarios presented above presuppose that the technological advances open new perspectives for primary energy supply, which will sustain the old consumption model, always directed towards an increasingly intense use of electricity. However, the technological argument itself might reverse that trend if it follows a line of efficiency increase of the final energy use, be it through the introduction of equipment, including more efficient electric appliances, be it through the substitution of electricity mainly for gas in the production the thermal power and of the motion power.

Such transformations can be believable as far as there is a trend for an energetic system increasingly orchestrated by the consumers' needs and by their capacity to impose new technological patterns. The investments in education and the growing mobilization of people concerning the global themes itself, which will affect the energetic issues, will be able to produce a perhaps unpredictable increase in relation to the technologies of rational and efficient use of energy. The final goal will be to match every final use of energy to the most appropriate energy source, through the most adequate technology, reducing the specific energy consumption and the environmental impacts.

In this path, the role of the fuel gases, adequating themselves optimally and with high value added to humanity's needs, might surpass all the predictions stated in the scenarios above. Natural gas will not only occupy the role of transition fuel towards the construction of new electricity generation matrixes, but will also occupy the central role of an energy matrix directed mainly towards the final service of thermal energy, that is, the generation of heat or cold. That is the broad gas civilization concept.

Therefore, gas will become the main source of dynamism of the technological development directed towards the best energy use. New supply chains, bringing gas consumers and producers close to one another, will be reconstructed. The logistical systems will undergo a transformation and the access to gas will become a priority. Gas will become the center of the global energetic geopolitics.

The construction of the gas supply systems will require great initial investments the development of which will take place in the long-term, involving both the most developed and the less privileged nations that have just entered the gas civilization. For example, for the scenarios predicted by the International Energy Agency for the world gas sector to come true, the IEA itself (IEA, 2003) estimates, in another study, the World Energy Investment Outlook 2003, that the investment to be accumulated by the natural gas industry between 2001 and 2030 will be close to 3.1 trillion dollars (or an average annual investment of 105 billion dollars).

In another survey, the Natural Gas Market Review 2006 (IEA, 2006b), the Agency confirms that the investments are expected to be robust. It is expected that between 2006 and 2010, close to 210 billion dollars are already bound in investments covering the entire gas chain. Besides, there was the identification of other previewed projects that could be implemented or not and that would require investments of another 300 billion dollars. IEA argues that such investments will hardly be able to take place without adequate economic, financial and political conditions.

Such issues are especially relevant in relation to the less developed countries. It might not be possible to build a gas civilization based exclusively on natural gas in all countries of the world. Countries with a growth rate of energy consumption such as China, India or those in Southeastern Asia have had a hard time to ensure a long-term and competitive natural gas supply. The strategies for the construction of LNG reception terminals, as well as the construction of long-distance gas pipelines connecting those markets to gas reserves located in Central Asia or Russia, have faced countless economic and political obstacles (for example, the need to cross such countries as Afghanistan and Pakistan to take gas to India). For many of those countries, the gas civilization will be based on great projects for the gaseification of coal (CTG), ensuring a domestic gas supply. Therefore, this is a broad vision of the fuel gases, originating from several sources, but that ensure the same efficiency, cleanliness, flexibility and availability of a secure supply of high-quality thermal power advantages in the final use.

The consideration of the fuel gases within a broader scope, overcoming the natural gas dimension, ensures the construction of a scenario with high availability of primary energy to sustain the gas civilization. Until 2030, the supply of natural gas seems to be sufficiently abundant. That situation may become less comfortable after 2030. The scenarios by Shell make explicit the growing role of CTG between 2025 and 2050, as a fuel complementary to natural gas. Besides, the gas civilization will have a greater energetic diversification. Oil and coal will keep some of its natural callings. However, in the same way that the geopolitics of coal lost its decisive character to define the future of the oil civilization, the fuel gases will guide the gas civilization, until

men free themselves of combustion to produce their thermal energy, through the use of fuel cells or other technologies that the scientific evolution might still make viable.

Historical background and future perspectives for gas in Brazil

The gas industry in Brazil began in the 19th century, producing gas from coal, mainly for public lighting. In that first phase, companies such as CEG (the gas distribution company in the city of Rio de Janeiro) and Comgás (currently the main gas distribution company in the State of São Paulo), were constituted. However, with the emergence of electricity in 1882, the gas industry's expansion was held back. The exception was LPG, produced from oil used almost exclusively for cooking in the urban centers, which had an important expansion throughout the 20th century, reaching more than 90% of the Brazilian households.

In the end of the 1970's and beginning of the 1980's there were some attempts to introduce natural gas to the Brazilian energy matrix. Among others, the beginning of the national gas provision, produced together with oil and supplied both in the Brazilian Southeast and Northeast. There were also the frustrated negotiations of Comgás to import LNG from Algeria. In the beginning of the 1980's, the National Industry Confederation (CNI) encouraged industries to use gas (CNI/Coase, 1982). However, it was in the beginning of the 1990`s that Brazil awoke once again to the potential of gas.

Despite the competition with its main business, the selling of oil by-products, Petrobrás Petróleo Brasileiro S.A. started to give more importance to the production and the supply of gas. The company discovered more gas reserves in the Brazilian sedimentary basins and it became important to value economically that natural resource by means of specific investments in infrastructure and in the creation of a demand for gas.

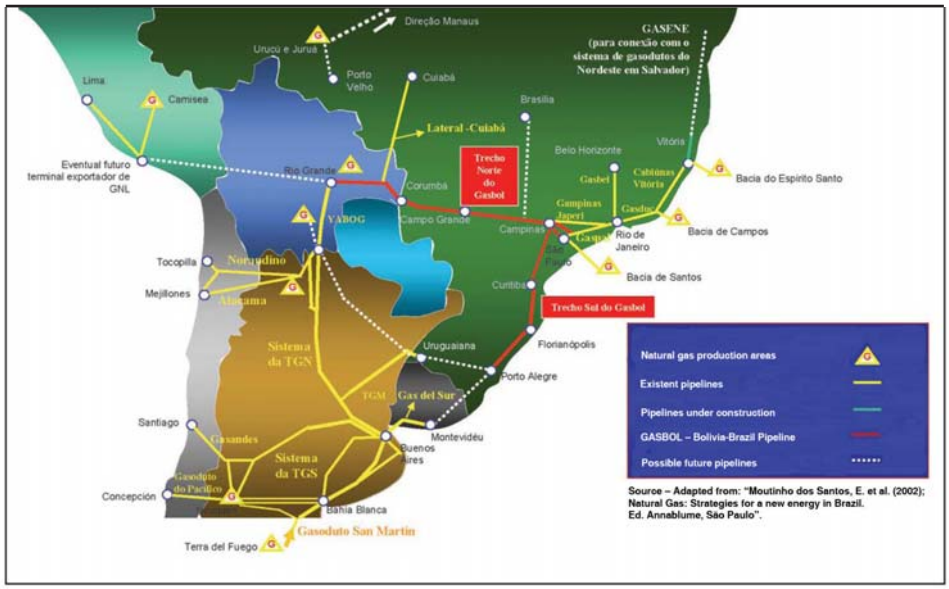
From 1990 on, Brazil also took upon itself more solid commitments with the regional economic integration, mainly with the creation of the Mercosul free trade zone. That political opening came true with the construction of a gas pipeline connecting Bolivia and Brazil, called Gasbol3 (Figure 1). Gasbol, which began its operations in 1999, re-launched the Brazilian gas industry since it permitted a large supply of gas at reasonable costs. In the city-gates, that is, in the delivery place of the gas to the distributors and traders, the Bolivian gas was initially sold at approximately 3.0 US$/MMBtu.4

Besides, as was discussed in Altmann et al. (2006), during the same period Brazil underwent an institutional restructuring process of the energetic sector, with particularly important effects in the gas sector. The main distribution companies, CEG and Comgás, were privatized, which

permitted the entrance of new economic agents with investment capacity and greater calling for gas. Such processes are still evolving, defying the old state monopolies by Petrobrás and Eletrobrás (and the other companies of the electricity sector), which were traditionally against the development of a gas market capable of threatening the control of oil and hydroelectricity in the national energy matrix.

In 1997, almost 10 MMm3/d were traded in Brazil.5 Since then, the market has grown more than 20% per year, reaching a total sales volume close to 28 MMm3/d in 2002. In the end of 2006, the Brazilian distribution companies sold more than 40 MMm3/d, and the growth rate of the market had a slight decline from 2003 on, when political tensions and greater uncertainties concerning the import of gas from Bolivia began to emerge. Even so, between 1997 and 2006, the annual average expansion of the Brazilian gas market was approximately 18%, much higher than the growth rate of total energy consumption in Brazil.

Figure 1 – The Gasbol pipeline and its integration role between the Pipeline Systems of the South, Southeast and Centerwest regions of Brazil and the other countries of the Southern Cone.



Despite that solid growth, the volume of natural gas traded in the end of 2006 corresponded to 13.2 million toe or the equivalent to 0.57% of the world's total gas consumption in 2004. Such a share may be considered ridiculous for a country that represents almost 4% of the world GDP and about 2% of the global oil consumption.

In relation to future scenarios for primary energy consumption in Brazil, Table 3 summarizes and compares two perspectives. The International

Energy Agency (IEA, 2006a) produced a "Reference scenario for Brazil". In turn, the Brazilian government, through its official agency for energetic research, EPE (2006), produced the "National energy plan to 2030".

Even starting from presuppositions that are very close to one another, there is a great discrepancy between both studies. For example, to 2030, EPE suggests that Brazil will require approximately 65% more primary energy than IEA's estimate. Throughout the entire analysis period, which is similar for both studies, total primary energy consumption is expected to grow at an annual average rate of 2.2% (according to IEA) and 4.0% (according to EPE). IEA believes that Brazil will follow a similar path to what has been predicted for the rest of the planet. That means that by 2030 there will be a decrease in the share of fossil energy sources such as oil and coal, being compensated by solid growth in the renewable and nuclear energy consumption. Nevertheless, the relative share of the set of fossil energy sources won't change until the end of the period, maintaining its dominant share: 57.6%.6

The always dominant share of the fossil energy sources is due to two phenomena. On the one hand, the consumption of traditional renewable energy, such as firewood, is expected to decrease. On the other hand, natural gas will be the energy source with the second highest growth rate throughout the period. By 2030, it will represent approximately 12% of the total energy matrix and 20% of the total consumption of fossil energy sources in Brazil (compared to 8% and 14% in 2004, respectively).

In the EPE scenario, Brazil tends to follow a different path from the rest of the world. The share of the set of fossil energy sources is expected to grow between 2005 and 2030. Oil will undergo a relative loss that will be compensated by solid increases in the consumption of coal and natural gas. Besides, EPE suggests an expansion of nuclear energy approximately 138% higher than what IEA has predicted. The relative expansion of natural gas will also be vigorous, and, in 2030, gas is expected to represent 15% of the Brazilian energy matrix (and 26% of the total consumption of fossil energy sources of the country).

Table 3 – Energetic scenarios for Brazil – IEA & EPE

IEA Scenarios						
	2004		**2015**	**2030**		**2004-2030**
	(MMtoe)1	**%2**	**(MMtoe) 1**	**(MMtoe) 1**	**%2**	**%3**
Coal	14.2	7.1%	15.1	18.0	5.2%	0.9%
Oil	84.8	42.4%	108.4	141.7	40.6%	2.0%
Natural gas	15.8	7.9%	25.9	41.2	11.8%	3.8%
Nuclear	3.0	1.5%	6.3	6.3	1.8%	2.9%
Hydroelectricity	27.6	13.8%	38.0	50.0	14.3%	2.3%

Biomass and wastes	54.4	27.2%	70.6	89.8	25.7%	1.9%
Other renewables	0.0	0.0%	0.5	1.9	0.5%	25.4%
Total fossil	114.8	57.5%	149.4	200.9	57.6%	2.2%
NG / Total fossil[5]		13.8%			20.5%	
Nuclear + renewable	85.0	42.5%	115.4	148.0	42.4%	2.2%
Total	**199.8**	**100.0%**	**264.8**	**348.8**	**100.0%**	**2.2%**
EPE Scenarios						
	2005		**2030**		**2005-2030**	
	(MMtoe)1	**%2**	**(MMtoe)1**	**%2**	**%3**	
Coal	13, 122	6.0%	40, 362	7.0%	4.6%	
Oil	85, 293	39.0%	207, 576	36.0%	3.6%	
Natural gas	19, 683	9.0%	86. 49	15.0%	6.1%	
Nuclear	2, 187	1.0%	11, 532	2.0%	6.9%	
Hydroelectricity	32, 805	15.0%	74, 958	13.0%	3.4%	
Biomass and wastes	59, 049	27.0%	121, 086	21.0%	2.9%	
Other renewables	6, 561	3.0%	34, 596	6.0%	6.9%	
Total fossil	118, 098	54.0%	334, 428	58.0%	4.3%	
NG / Total fossil [5]		16.7%		25.9%		
Nuclear + renewable	100, 602	46.0%	242, 172	42.0%	3.6%	
Total	**218.7**	**100.0%**	**576.6**	**100.0%**	**4.0%**	

Where:
1 – In million of tons of oil equivalent.
2 – Share % of the source in the annual matrix.
3 – Average annual growth rate % of the source between 2004 and 2030.
4 – Includes firewood, sugar cane by-products and charcoal.
5 – Share % of the natural gas consumption on the total consumption of fossil energy in the year.
Source: International Energy Agency & Energy Research Company.

The comparative analysis of both scenarios allows us to consider the solid growth of the natural gas consumption as one of the solid trends for the Brazilian energetic evolution, similar to what is expected globally. EPE believes that in 2030 Brazil will consume approximately 110% more gas than IEA predicts. According to that EPE scenario, in 2030 Brazil will consume approximately 2.2% of all gas consumed in the world. In the IEA scenario, the Brazilian share in global gas consumption in 2030 will be 1.1%.

Therefore, it can be argued that Brazil is also heading to an energetic framework in which natural gas will play a more relevant role. However, the country is still far away from a gas civilization, as it was defined above. It is very likely that the Brazilian transition to a gas civilization will be hindered due to the maintenance of a strong Brazilian calling to use hydroelectricity as its final power. That situation is preserved within the predictions of both EPE and IEA.

The model of dominant hydroelectric generation allowed Brazil to use the abundant electricity generated indiscriminately, without setting priority uses. The scenarios presented above go in the same direction. For example, the option for gas is preferably directed towards its use as fuel in thermal power plants. Besides, there is a perspective of a solid enlargement of the generation park with the construction of new hydroelectric and nuclear power plants. The nuclear preference of the EPE scenario is particularly harsh. The maintenance of that model avoids any challenges to deeply rethink the matrix of final energy uses. The alternative use of gas, replacing electricity and promoting the Brazilian entrance in the gas civilization is hindered and considered only marginally by both scenarios.

The construction of the gas civilization in Brazil requires a perspective of the future focused on the energetic needs of the consumers and in the use of the energy's quality in the final uses. A solid commitment of the country is also necessary to overcome important structural disadvantages of gas in the Brazilian reality. Particularly, the lack of key infrastructure for its transportation and distribution from the production areas to the final consumers, will involve great investments.

The construction of a gas transportation and distribution logistics represents an important obstacle for the Brazilian consumers to have access to gas. Even though the Brazilian economic situation has had a great improvement in relation to the troubled decades of 1980 and 1990, it still suffers from an important lack of investments and scarce supply of cheap and long-term sources of capital, which are necessary for the construction of the gas civilization. The act of turning feasible the construction of the gas supply chains involves complex financial engineerings based on the existence of solid and sufficiently mature markets to be served.

In the Brazilian case, there has often been an attempt to base such investments on the construction of great gas thermal power plants. The success of that strategy will postpone the logic of the indiscriminate use of electricity, transforming the gas civilization in a remote perspective for the country. In practice, however, at least until now, that strategy of electricity produced by means of gas thermal power plants has not proved to be sustainable. That makes the gas industry in Brazil seem always in the brink of crises and is scarcely reliable and attractive to the consumers. Therefore, the scenarios above tend to lose any representative character.

Entering the gas civilization in Brazil involves, above all, an important cultural change in the relation between man and energy which, in turn, involves a dimension of technology and knowledge. It's about promoting an energetic transition to make the use of electricity rational and to ensure that gas can occupy its most legitimate spaces. Such transition may be consolidated in the next fifty years by means of consistent policies. In that transformation, society will gradually abandon what might be considered the greatest distortion of the Brazilian energy matrix, which is the exaggerated use of electricity as final energy, even for the production of heat and cold.

Therefore, Brazil will move towards the construction of a more diversified energy matrix in the field of the final use of energy, with new options of primary sources meeting its most adequate uses and with a clear leadership of natural gas, mainly in the production of high quality thermal energy. That option will represent the consolidation of the real gas civilization in the country. This is a totally different model from the one that supports the scenarios presented in Table 3. In it, the focus is to simply diversify the primary energy sources for the production of more electricity, also with a great motivation for nuclear energy (in the proposal by EPE).

The solidification of the gas civilization in Brazil will depend on the process of knowledge and technology creation aiming at the greater rationality and efficiency of the final use of energy. In Brazil, there is very limited understanding about the most adequate technologies for burning gas, with high value-added and promoting that greater energetic rationality. The technologies are not available and its import or its development domestically is not encouraged. Therefore, it is very unlikely a great diffusion of the interest for the consumers to convert themselves to the gas world.

The lack of interest by the consumers is nurtured by as their access to gas becomes increasingly limited. The structural disadvantages become permanent obstacles that inhibit the competitiveness of gas in relation to other power sources. The logistics of gas is restrictive for the development of the market and it becomes ever more restraining when its priority use is given to the electric sector itself, seeking to reserve gas availabilities for its thermal power plants. The consumer tends to lose its confidence in relation to the security of the gas supply for other uses. The consumers themselves don't press on the rulers responsible for the energetic policy to restrict the difficulty of access to gas. On the contrary, gas is seen as an interesting back-up to reduce the supply risks of a model directed towards the indiscriminate consumption of electricity. Even if that enforces complete irrationality to the construction process of the gas industry.

There could be alternative technological solutions for the infrastructure obstacles with the construction of loose supply systems that are cheaper, have greater flexibility and permit a faster access to gas, anticipating the

consolidation of the new gas civilization. However, that effort also requires new conceptions and a focus on the final use of gas, aiming at the direct production of thermal energy. New conceptions regarding the logistics of energetic supply would have to be incorporated, no longer promoting only great duct network structures, but also using the highway, railway and waterway infrastructure already existent in the country. Such options are not considered in the EPE and in the IEA scenarios. Therefore, the promising future view that those scenarios project for gas in Brazil can hardly be translated as the entrance of the country in the gas civilization.

Conclusion

This paper presented a concept that is both polemical and still not completely absorbed by the literature directed towards the energetic issues, which is that of gas civilization. It refers to an energetic world the useful life of which is expected to be extended throughout the next century, materializing a growing leadership of the fuel gases in the world energy matrix. There was an attempt to demonstrate the logic, the presuppositions and the difficulties for the accomplishment of that new energetic civilization. The Brazilian reality was specifically considered, revealing even greater difficulties for gas in a country the main energetic calling of which is the intensive use of electricity as final energy.

It was demonstrated that, despite all the potential benefits that natural gas can provide to the consumers, several cultural, technological and economic barriers inhibit its adoption as the main energy source. Without a revolutionary process for the creation of gas knowledge, technology and culture that favors the penetration of gas in legitimate final uses such as thermal energy and moving power, the development of the gas markets becomes very risky. The funding of gas pipelines and of all infrastructure related to the production, transportation, distribution and final use of the gas also becomes difficult and it inhibits the structuring process of the gas civilization.

All the scenarios presented above indicate a solid growth of energy consumption, leading to the belief that the world energy matrix won't undergo any substantial alteration in the next few decades. That is a hypothesis that could be discussed even though it was not the focus of this paper. The fossil energy sources will continue to prevail and natural gas will play an even more relevant role.

It is important to note that, even though they predict solid growth rates of the share of gas in the world energy matrix, such energetic scenarios are unlikely to lead to the gas civilization concept, since the gases merely assume a growing role as alternative primary energy for electricity generation.

In the case of less developed countries such as Brazil, the construction of the gas civilization will hardly be able to be accomplished with the financial resources and the energetic policies currently available. To by-pass that

situation the developing countries would have to use the new technology so they wouldn't have to perpetuate a background of an exaggerated and almost endless growth of the energetic consumption, as a whole and of electricity, specifically. An initial problem is the costs of those technologies, which the poor countries may not necessarily be able to afford. However, their technological exclusion lead to an irrational global energetic system, with the unnecessary squandering of increasingly scarce energetic resources, as well as growing environmental impacts that could be avoided through the greater efficiency in the final use of energy.

In Brazil, the strategy to develop the gas civilization seems to strive for preferences mainly in relation to revitalization of nuclear energy. As far as nuclear is concerned, it is worth noting the role that EPE reserved to its growth in the Brazilian energetic matrix until 2030. Such energy is exclusively directed towards electricity generation. Therefore this is about promoting the opposite of the gas civilization. In that same scenario a solid growth in the share of gas in the energetic matrix is also foreseen, even though the emphasis is electricity production. Once again, there is the support of the maintenance of the indiscriminated use of electricity as final energy and a progressive departure from the gas civilization.

In this paper, there was an attempt to encourage a reflection about the breaking of energetic paradigms necessary for the development of a gas civilization. The nations not always find the means that allow them to overcome the obstacles to reach that goal. The traditions of an energy matrix already based on other energy sources, which are related to other interest groups, continuously recreate new obstacles that hinder the birth and the development of a vigorous and civilizing gas industry. Indeed, as was emphasized throughout the text, entering the gas civilization involves, above all, cultural changes, which will only be possible by means of significant efforts in the generation of technology and knowledge for the best final use of energy. That is the main civilizing effect of gas.

Brazil presents an important example related to the changing of fuel consumption habits, which is the alcohol program. In a certain way that program faced, throughout history, very similar obstacles to those that occur with natural gas today. However, Brazil can be proud of being the only country in the world with cars that can use gasoline and alcohol in any proportion, as well as a significant share of biofuels use in the transportation sector. There is a competitive advantage that may be explored, even though that energetic option involves, itself, its own problems that must still be solved. Brazil was also a pioneer in the production of offshore oil in deep waters. Once again, after some criticisms are overcome, that is a unique experience by a less developed country using its capacity to generate technology and knowledge to obtain competitiveness in the energetic sector.

If Brazil is able to profit from the potential advantages of gas and is able to review its history in relation to that energy source, it will profit, once again, from a historic opportunity to ensure greater energetic efficiency in a world that is increasingly restrictive in the availability of the primary energy sources and in the ability to absorb environmental impacts.

Otherwise, if the tendency for energetic planning based only on the energy supply prevails, it will lose an opportunity to be a pioneer in the gas civilization, as well as to move towards a greater energetic independence. Not a nationalist independence, in the same pattern as the one of 1970's, which was concerned exclusively with a self-sufficiency of cheap energy production (which always comes back as other costs for society). The real energetic independence is obtained creating high value-added productive forces within the nation, which are able to afford the much more expensive energy of the future. That much more expensive energy must be used in a much more responsible manner. The development of the gas civilization is a crucial step towards a world in which men will be more responsible for the future of their planet.

Notes

1 The substitution of gasoline for VNG – mainly encouraged by fiscal incentives applied on fuels, in a country like Brazil, in which, for the light vehicles, there is still the option to use alcohol, in cars the prevailing technology of which becomes the so-called flex-fuel (alcohol and gasoline) engines – deserves a deeper debate, which will be avoided in this essay. Meanwhile, diesel oil continues to be the prevailing fuel in the Brazilian transportation system, representing more than 50% of total consumption. The use of vehicle gas in trucks or bus is still ridiculous, challenging those interested in modifying the fuels matrix for heavy vehicles in the country.

2 The presuppositions of each study won't be presented, acknowledging that such an absence jeopardizes its comparative reading. However, the goal is to try to identify "solid trends", that may be present despite the details or the different hypotheses that sustain each scenario.

3 Gasbol is about 3, 200 kilometers long, of which approximately 2, 600 kilometers are within the Brazilian territory, connecting the Brazilian-Bolivian border to the city of Porto Alegre, in the extreme South of the country. In the Brazilian side, the gas pipeline has two sections. Its Northern section is the largest one, with approximately 1, 400 kilometers, connecting the border to the State of São Paulo. The Southern section of the Gasbol pipeline runs for almost 1, 200 kilometers from São Paulo to Porto Alegre.

4 Where: MMBtu = Million British Thermal Units. A price of 3.0 US$/MMBtu was equivalent to an oil price slightly lower than 18 US$/barrel. That could be considered moderate for a better quality fuel, even back in the end of the 1990's, when the energy prices were low in the international market. Even though national gas was sold at lower prices, Petrobrás never made available an abundant supply of that gas, capable of altering substantially the Brazilian energy matrix.

5 Where: MMm3/d = Million cubic meters per day. The volume of 10 MMm3/d is equivalent to 3.3 million toe per year. In other words, the consumption of gas in Brazil in 1997 was equivalent to 0.23% of the world consumption registered in 1980.

6 It can be noted that, in Brazil, the share of fossil energy sources is historically lower than that for the rest of the world. That particular aspect reflects the great availability of natural resources in the country, including water, land and solar radiation, which convey a mineral, agricultural and agro-industrial calling of the Brazilian economy. That calling, along with the availability of resources, privileges energetic policies that tend to favor the renewable energy sources.

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Abstract – This paper discusses the role of natural gas in Brazil and in the world, suggesting that humanity is building up a kind of gas civilization. The text starts with a brief panorama of the international energy reality comparing several scenarios proposed by recognized institutions, and which try to describe possibilities for the future of energy in the planet. Such comparative analysis allows identifying the growing consumption of natural gas as a "strong energy trend" for the next 20 to 50 years. Then, the concept of gas civilization is introduced, presenting some elements that justify it. Then, the article offers a Brazilian perspective of the problem, starting

from the historical antecedents of the gas industry in Brazil and developing a critical vision regarding the future role of the combustible gases in the Brazilian energy matrix.

Keywords: Energy matrix, Natural gas, Combustible gases, Gas civilization.

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